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The effect of the local and global weld geometry as well as material defects on crack initiation and fatigue strength

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ABSTRACT

The paper provides an application of the IBESS approach to the investigation of the influence of various parameters of the global and local weld geometry as well as material defects on the fatigue strength of weldments. For this purpose, the global weld parameters, such as the weld toe radius, the flank angle, the excess weld metal, local secondary notches (in the present study as a measure of surface imperfections) and inclusions sizes have been determined as statistical distributions for different joint types and geometries and two steels of different strengths. The results are in line with literature data and reveal the potential of the theoretical approach to predict the correct trends. The combination with an advanced weld quality system has been demonstrated to be possible.

1. Introduction

Fatigue crack initiation and early crack propagation at the weld toe, which control a large part of the total fatigue lifetime of weldments are strongly influenced by the global and local geometry of the weld. The investigations within the cluster project IBESS, although limited to weld toe cracks, covered various weld configurations. Therefore the discussion on the geometry parameters and crack initiation sites in this publication is limited to weld toe cracks. Fig. 1 provides an illustration of the investigated parameters. These are the weld toe radius ρ, the flank angle α, the excess weld metal height h and the secondary notch depth k (the meaning of the latter will be explained in detail in Section 3.2). A further investigated parameter is the weld width L which was, however, not considered within the fracture mechanics analyses for butt welds.

Abbreviations: FAT, FAT-class (stress range referring to $N = 2 \cdot 10^6$), IIW nomenclature; HAZ, Heat Affected Zone; IBESS, Integrale Bruchmechanische Ermittlung der Schwingfestigkeit von Schweißverbindungen (Title of the German cluster project = Integral method for fracture mechanics determination of the fatigue strength of weldments); IIW, International Institute of Welding; MAG, Metal Active Gas welding; TIG, Tungsten Inert Gas welding.

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Nomenclature

a	crack length (crack depth for surface cracks)
a/c	crack aspect ratio
c	half crack length at surface (semi-elliptical crack)
$F(x)$	cumulative distribution function of a parameter x
h	excess weld metal height (Fig. 1)
k	secondary notch depth (e.g. undercut or surface roughness)
k	slope of the finite life S-N curve ($k = \Delta(\log N)/\Delta(\log \sigma_a)$)
K	stress intensity factor
L	weld width (Fig. 1)
ℓ	section width (weld toe, Figs. 10–12, 14)
N	number of loading cycles
N_f	number of loading cycles to failure
P_t	roughness parameters of the primary profile
R	load ratio ($R = K_{min}/K_{max} = \sigma_{min}/\sigma_{max}$)
R	roughness parameter of the roughness profile according to the former DIN 4762 standard (Section 3.2)
R_z	roughness parameter of the roughness profile (Section 3.2)
R_m	tensile strength
T	plate thickness
Var	coefficient of variation, ratio of the standard deviation to the mean value
s, α	fit parameters of the Frechet distribution (Fig. 20)
α	weld flank angle (Fig. 1)
$\Delta\sigma$	stress range ($\sigma_{max} - \sigma_{min}$)
ΔK_{th}	fatigue crack growth threshold ($K_{th,max} - K_{th,min}$)
μ	mean value
μ, β	fit parameters of the Gumbel distribution (Fig. 20)
ρ	weld toe radius (Fig. 1)
σ	stress
σ	standard deviation
σ_a	stress amplitude (=½ $\Delta\sigma$)
$\sigma_{a,e}$	fatigue limit (stress amplitude)

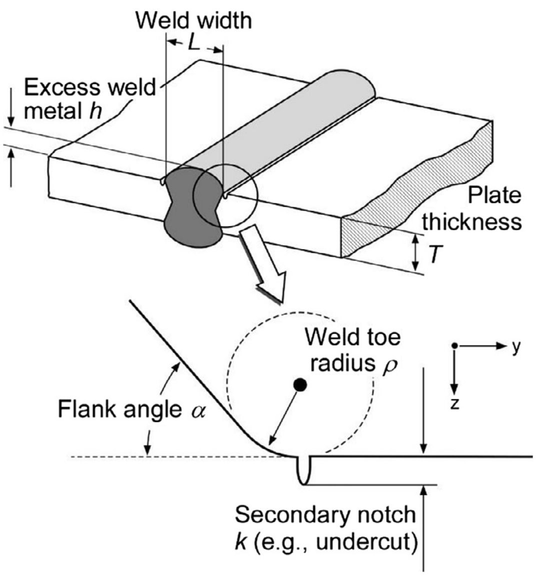

Fig. 1. Parameters describing the global and local weld geometry.